

MANAGEMENT OF CITRUS ROOT WEEVILS (COLEOPTERA:  
CURCULIONIDAE) ON FLORIDA CITRUS WITH  
SOIL-APPLIED ENTOMOPATHOGENIC NEMATODES  
(NEMATODA: RHABDITIDA)

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ABSTRACT

The entomopathogenic nematodes *Steinernema carpocapsae* Weiser and *S. riobrav*is Cabanillas, Poiner and Raulston were compared as twice a year soil treatments for control of the west indian sugarcane root stalk borer weevil, *Diaprepes abbreviatus* (L.), and citrus root weevil, *Pachnaeus litus* (Germar). Additionally, four single rate demonstrations evaluated *S. riobrav*is and a 2- year test compared single versus double annual treatments of *S. riobrav*is. The 6 experiments were conducted in the Indian River Area of Florida, U.S.A.

Two applications per year of *S. carpocapsae* were as effective as *S. riobrav*is for *P. litus* control but failed to control *D. abbreviatus*.

A single application of *S. riobrav*is delivering 2 million nematodes per tree through low volume irrigation systems or a tractor-mounted herbicide boom in demonstration tests provided 64% and 89% reduction of *P. litus* and *D. abbreviatus*, respectively.

Single annual applications of 2 million *S. riobrav*is per tree delivered with sprinkling cans reduced *P. litus* populations by 65% and *D. abbreviatus* populations by 85% over a 2 year period and was statistically equal to a 2-a-year treatment of *S. riobrav*is that provided 80% and 95% reductions, respectively.

Key Words: *Diaprepes abbreviatus*, *Pachnaeus litus*, root weevils, citrus, *Steinernema carpocapsae*, *S. riobrav*is

RESUMEN

Se comparó durante un año el efecto de dos tratamientos al suelo de los nemátodos entomopatógenos *Steinernema carpocapsae* Weiser y *S. riobrav*is Cabanillas, Poiner y Raulston para el control del picudo antillano de la caña, *Diaprepes abbreviatus* (L.), y el picudo de los cítricos, *Pachnaeus litus* (Germar). Se evaluó además el efecto de una sola aplicación de *S. riobrav*is en cuatro ensayos. En un ensayo adicional realizado durante 2 años se comparó el efecto de una sola aplicación por año y de dos aplicaciones anuales de *S. riobrav*is. Estos 6 ensayos fueron realizados en el área de Indian River en Florida, E.U.A.

Dos aplicaciones al año de *S. carpocapsae* fueron igual de efectivas como dos aplicaciones de *S. riobrav*is para el control de *P. litus*, pero *S. carpocapsae* no controló a *D. abbreviatus*.

Una aplicación de una dosis de 2 millones de nemátodos por árbol de *S. riobrav*is, utilizando un sistema de irrigación a bajo volumen, o utilizando un tractor con sistema de aplicación para herbicidas, resultó en una reducción del 64% y 89% de *P. litus* y *D. abbreviatus*, respectivamente.

Una sola aplicación de 2 millones de *S. riobrav*is por árbol utilizando regaderas manuales dió como resultado una reducción del 65% de la población de *P. litus* y del

85% de *D. abbreviatus* durante dos años y no difirieron estadísticamente de dos tratamientos por año, lo cual dió como resultado una reducción del 80% y 95% para cada especie, respectivamente.

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In the 34 years since its detection in Florida, the west indian sugarcane rootstock borer weevil, *Diaprepes abbreviatus* (L.), has spread from the original find in an Apopka, FL, citrus nursery (Woodruff 1968) to approximately 11,364 ha of citrus groves distributed in 19 Florida counties (Hall 1994). Annual losses and cost of control in citrus currently exceeds 72 million dollars to citrus growers (Stanley 1996).

Attempts to control *D. abbreviatus* have passed through failed initial eradication efforts, suppression with chemical sprays and soil treatments (Bullock 1985, Bullock et al. 1988, Bullock and Pelosi 1993, McCoy et al. 1995, Quintela and McCoy 1997) to biocontrol efforts prompted by discovery of natural agents recovered in soil surveys conducted by Beavers et al. in 1983. Some of the entomopathogens discovered have been investigated (McCoy and Boucias 1989) and a synergism identified between pathogens and the insecticide imidacloprid (Quintela and McCoy 1997).

The nematode component of the Beavers et al. survey generated a body of research that identified *Steinernema carpocapsae* Weiser as a soil treatment for control of larvae (Schroeder 1987, 1990, Downing et al. 1991, Adair 1994, Bullock and Miller 1994). The commercial product BioVector™, containing *S. carpocapsae* All strain as its active ingredient, became available to growers. After the discovery of *S. riobraivis*, in Texas' Rio Grande Valley (Cabanillas et al. 1994), Schroeder (1994) compared it with *S. carpocapsae* for control of *D. abbreviatus* larvae under controlled conditions. He found it superior to *S. carpocapsae* and its early promise has been confirmed by field tests reported here.

#### MATERIALS AND METHODS

The research reported here was conducted during the Spring of 1994 in four citrus groves in the Indian River Area of Florida. A fifth grove provided data from a 3-year study. All groves were infested with *D. abbreviatus* and the citrus root weevil, *Pachnaeus litus* (Germar).

Grove No. 1, in Indian River County, was treated 23 March. This 20-year-old block of double bedded 'Marsh' grapefruit trees, planted at a 3.6 x 6.9m spacing, was treated at the rate of 1.6 million nematodes per tree delivered in water at 85 GPA through a tractor-mounted herbicide boom and applied to a pre-irrigated, surface-littered grove floor area beneath the tree canopy. Both sides of the tree row were treated. Treatments were replicated four times in 50-tree plots. Conical hardware cloth ground traps (0.66m<sup>2</sup> at base, 60 cm tall), capped with 0.95 liter clear plastic cups (Paradise Plastics, Plant City, FL) attached by 15 cm long braided elastics (Goody Products, Peachtree, GA), were placed next to the tree trunks to monitor weevil emergence from nematode treated (n = 100) and water treated (n = 100) soil.

Grove No. 2, in Indian River County, was treated 23 March by injection of *S. riobraivis* into the microirrigation system at a rate delivering 2 million nematodes per tree. Treatments were replicated six times in 28-tree plots. Irrigation laterals, serving single rows of 10-year-old 'Marsh' grapefruit trees planted at a 6x9m spacing were closed during treatment application. When nematode delivery was completed, the irrigation lines were purged, laterals opened to allow water flow to control plots and the

block received additional irrigation provided to facilitate nematodes movement into the soil. Ground traps were placed next to 100 trees in the treated and 100 trees in untreated plots.

Grove No. 3, in Indian River County, was treated 24 March by injection of *S. riobravis* into the microirrigation system at a rate delivering 2 million nematodes per tree. Treatments were replicated 3 times in 46-tree plots. Irrigation laterals, serving the paired rows of 6-year-old 'Minneola' tangelo trees planted at a 3.7 × 9m spacing on double beds, were closed during treatment application. When completed, the lines were purged, laterals opened and the block received additional irrigation to facilitate the nematode movement into the soil. Ground traps were placed next to 100 trees in the treated and at 100 trees in control plots.

Grove No. 4, in St. Lucie County, was treated 14 April. A 2 quart suspension of Bio-Vector 355, containing 1.2 billion *S. riobravis*, was mixed with water in a pail. The slurry was poured into the reservoir for injection through the microirrigation system to a block of 'Marsh' grapefruit trees planted at a 3.75 × 9m spacing on single beds. Each tree received 2 million nematodes. Soil had been pre-moistened by 1.91 cm of rain the day before. When treatment was completed, irrigation lines were purged and blocked laterals that prevented water flow to beds with control trees opened. An additional half hour of irrigation to all the blocks delivered 5 gallons of water per tree to facilitate movement of nematodes into the soil. Ground traps were placed at the base of 100 treated and 100 control trees and were examined weekly for presence of emerging adult weevils.

The experiment in grove No. 5 was established in a block of 7-year-old, double-bedded 'Ruby' grapefruit trees, planted at a 5.4 × 7.2m spacing, at the IFAS IRREC in Ft. Pierce. Treatments were replicated 3 times in 34-tree plots and compared two applications (spring and fall) of *S. riobravis* with 2 applications of *S. carpocapsae* annually. One hundred untreated trees served as controls. Treatments were applied in March and September 1994. During treatments, 2 million nematodes suspended in a gallon of water were applied with a sprinkling can to the pre-moistened soil at the base of each tree in each of the treatments. One hundred ground traps were placed at 100 trees in each treatment plus 100 untreated trees and were examined weekly for presence of emerging adult weevils. Data were collected for one year, 1994. In grove N. 5, during April 1995, a single annual *S. riobravis* treatment was substituted for the twice-a-year *S. carpocapsae* and the experiment continued for 2 years comparing single with double applications of *S. riobravis*.

#### RESULTS AND DISCUSSION

The four short-term demonstrations conducted in the spring of 1994 provided an over-all 89% reduction of *D. abbreviatus* and 64% of *P. litus* (Table 1). Two treatments per year of *S. riobravis* provide 98% and 82% reductions of *D. abbreviatus* and *P. litus*, respectively, compared to 7% and 53% reductions resulting from the *S. carpocapsae* treatments (Table 2, 1994). However, the efficiency of the *S. carpocapsae* treatment, although providing a mediocre 53% reduction, was statistically equal to that of *S. riobravis* in reduction of *P. litus* populations.

The results of the 2-year study comparing one versus two applications of *S. riobravis* (Table 2, 1995, 1996) suggest that, although two applications per year would provide a greater average percentage reduction, the difference in performance was not statistically significant. A total of 1,611 weevils were collected in the course of the experiment in Grove 5. Weevil pressure remained constant through the 3 years with control traps yielding in excess of 300 adults per year.

TABLE 1. CAPTURE OF ADULT WEEVILS IN GROUND TRAPS AT FOUR DEMONSTRATION PLOTS.

		Total weevils $\pm$ SEM collected in 100 ground traps in following groves treated with <i>S. riobravis</i> : <sup>a</sup>				
		Grove Number				
Weevil Species		No. 1	No. 2	No. 3	No. 4	Average % Reduction
D. abbreviatus	Treated	0 $\pm$ 0.00 b	9 $\pm$ 0.25 a	28 $\pm$ 0.35 b	2 $\pm$ 0.28 b	89%
	Untreated	40 $\pm$ 0.49a	6 $\pm$ 0.32 a	59 $\pm$ 0.48 a	249 $\pm$ 1.10 a	
P. litus	Treated	6 $\pm$ 0.37 b	2 $\pm$ 0.27 b	0 $\pm$ 0.00 a	62 $\pm$ 0.15 b	64%
	Untreated	60 $\pm$ 0.55a	15 $\pm$ 0.04 a	6 $\pm$ 0.61 a	113 $\pm$ 0.40 a	

<sup>a</sup>Separation within columns by paired t-test, 5% level.

TABLE 2. CAPTURE OF ADULT WEEVILS IN 100 GROUND EMERGENCE TRAPS AT GROVE NO. 5.

Nematode Species	Total adult weevils $\pm$ SEM caught by year: <sup>z</sup>				Average % Reduction
	1994 <sup>x</sup>	% Reduction	1995	1996	
<i>S. carpocapsae</i> X2 <sup>y</sup>					
<i>D. abbreviatus</i>	145 $\pm$ 1.83 a	7%			
<i>P. litus</i>	79 $\pm$ 0.88 b	53%			
<i>S. riobravivis</i> X2					
<i>D. abbreviatus</i>	4 $\pm$ 0.33 b	98%	10 $\pm$ 0.49 b	19 $\pm$ 0.39 b	95%
<i>P. litus</i>	30 $\pm$ 0.51 b	82%	22 $\pm$ 0.40 b	36 $\pm$ 0.56 b	80%
Untreated					
<i>D. abbreviatus</i>	165 $\pm$ 1.94 a		281 $\pm$ 1.05 a	267 $\pm$ 2.49 a	
<i>P. litus</i>	167 $\pm$ 1.18 a		109 $\pm$ 0.55 a	135 $\pm$ 0.75 a	
<i>S. riobravivis</i> X1					
<i>D. abbreviatus</i>			50 $\pm$ 1.26 b	31 $\pm$ 0.86 b	85%
<i>P. litus</i>			43 $\pm$ 0.81 b	43 $\pm$ 0.54 b	65%

<sup>x</sup>Separation of totals within columns by Duncan's Multiple Range Test, 5% level.

<sup>y</sup>X2 = applications in march and September; X1 = march application only.

The results of these tests suggest that the success obtained in studies by Schroeder (1994) in lab bioassay and in potted citrus can be anticipated in the field. The comparison between *S. carpocapsae* and *S. riobravis* in 1994 (Table 2) indicates that the citrus industry would benefit from commercialization of *S. riobravis* as a replacement for *S. carpocapsae* in management of both *D. abbreviatus* and *P. litus*.

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